MECHANICAL SYSTEMS THESIS PROPOSAL

OCEAN COOLING, SOLAR HEATING, DESICCANT CONDITIONING

Rendering courtesy of Diller + Scofidio

INSTITUTE OF CONTEMPORARY ART

FAN PIER, BOSTON

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By

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Mechanical Option
December 2, 2004

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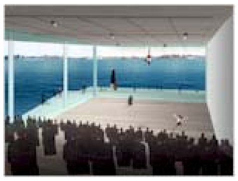
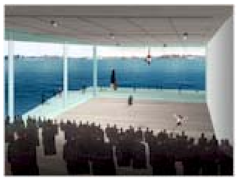


EXECUTIVE SUMMARY

This report presents a redesign proposal for the mechanical systems within the Institute of Contemporary Art, destined for completion in July of 2006 along the banks of Boston's Harbor. The following proposal outlines preliminary information to implement systems including: (1) ocean source cooling, (2) solar heating, and (3) desiccant conditioning. The objectives of this thesis research include lowering life cycle costs, decreasing first cost, increasing redundancy, and minimizing the building's impact on the environment. Further day-lighting enhancements and cost-cutting measures will be applied to the roof system of the Institute of Contemporary Art. A structural analysis will be performed to ensure proper support of solar panels and hot water storage tanks. Electrical equipment and systems will be analyzed and downsized where applicable. The final aspect of the redesign will involve an acoustical study to see if further cost saving measures can be implemented due to the complete elimination of the chiller, cooling tower, and related equipment. The scope of this proposed mechanical redesign is explained, justified, and discussed in terms of total building system integration. Finally, a preliminary schedule outlines the steps and required time needed to complete this thorough study.



BUILDING BACKGROUND

The new waterfront building will be the primary home for the Institute of Contemporary Art (ICA) in an attempt to house its unprecedented growth rate over the last five years. The ICA is a non-profit institution devoted exclusively to the presentation of contemporary art and has earned its place as one of New England's most vibrant cultural organizations.

The bold architectural statement from Diller & Scofidio along with a dramatic waterfront location entwine to produce a vibrant, high tech center for thought provoking showcase space, performances, and instructive activities. The Institute of Contemporary Art anticipates developing and displaying a diverse permanent collection of art comprised in various media formats, which have acted as the driving catalyst for the architectural program.

Viewing these works of art in natural daylight was a prime objective of the institution and consequently influenced many of the architectural components comprising the new Institute of Contemporary Art. North facing skylights will facilitate natural light throughout the building's main gallery halls, which will be located on the 4^{th} floor.

Numerous architectural explorations eventually led to a design surprisingly sensible and straightforward: a steel-frame box building with a column-free 4th level that will radically cantilever out over Boston's harbor. The cantilevered design embraces a public harbor walk and produces ever-changing panoramic spectacles of the water's edge. Design and construction of a new museum in Boston is an uncommon incidence and opportunity. The new building for the ICA will be the first art museum to be built in Boston in almost 100 years and is destined to embody the architectural potentials of the nation's most historic cities. In that milieu, it is anticipated that the design creates a pioneering breakthrough museum for art of the 21^{st} century.

The overall size of the project is about 60,000 ft^2. The total costs for the project are estimated to be in the region of $45 million of which about $ 30 million are allocated for building construction. Construction is planned to be complete by July 2006.

AIRSIDE SYSTEMS

The building is served by five (5) air handling units, ranging from 4,000 cfm to 32,000 cfm.

1) AHU-3 (32,150 CFM): The lobby, retail, administration, and dining room spaces on 1^{st}, 2^{nd} and 3^{rd} floor levels are served by a variable air volume (VAV) air-handling unit located on the Center Spine Roof (AHU-3). Air is distributed to different zones through VAV boxes, which will vary the amount of air supplied to each zone based on its cooling or heating needs. AHU-3 includes particulate filters, preheat and cooling coils, supply and return fans.
2) AHU-4 (22,500 CFM): A constant air volume (CV) air handling unit located on the Center Spine Roof (AHU-4) serves the theater located on the 2nd and 3rd floor levels. AHU-4 includes particulate filters, preheat, reheat and cooling coils, supply and return fans.
3) AHU-1 (21,150 CFM): A constant volume (CV) air handling unit located on the Center Spine Roof (AHU-1) will serve the Permanent Gallery and North Gallery (half of the space) on 4th floor level. AHU -1 includes particulate filters, preheat, reheat and cooling coils, humidifiers, supply and return fans.
4) AHU-2: (20,890 CFM): A constant air volume (CV) air-handling unit located on the Center Spine Roof (AHU-2) will serve the Temporary Gallery and North Gallery (half of the space) on 4th floor level. AHU-2 includes particulate filters, preheat, reheat and cooling coils, humidifiers, supply and return fans. Airside economizer allows energy conservation during non-peak outdoor conditions. The two air handling units serving the 4^{th} floor Gallery spaces (AHU-1 and AHU-2) will be cross-connected to provide redundancy to the space in case of failure of one of the units.
5) AHU-5 (4,090 CFM): A constant air volume (CV) air-handling unit located on Mezzanine MER (AHU-5) will serve the Mediatheque on the 4^{th} floor level. AHU-2 includes particulate filters, preheat, reheat and cooling coils, humidifiers, supply and return fans.

The areas in the building that will require humidification are as follows:

- West Gallery (Zone 41)
- East Gallery (Zone 38)
- North Gallery (Zone 39 and 42)

Two (2) gas fired steam generators located in the Mezzanine MER will generate this steam. Each generator is sized for 50% of system capacity to provide low load control and a measure of system security. Steam supply and condensate return piping is comprised of stainless steel. The two air-handling units serving the Galleries (AHU's 1 & 2) are provided with a humidification section built into them including direct steam dispersion grids with connecting control valves.

WATERSIDE SYSTEMS

Cooling media for the Institute of Contemporary Art will be chilled water (CHW). Chilled water is provided by two (2) chillers located along the center spine roof. The total estimated chiller load for the building is 280 tons while each chiller is sized for 140 tons or 50% of the total cooling capacity. Chilled water (35% propylene glycol) will be supplied to the building at 45ºF supply with a return water temperature of 55ºF. A variable volume pumping system distributes water throughout the building. Air-cooled towers are responsible for dissipating heat.

The Institute of Contemporary Art is comprised off the following equipment burning natural gas:

- Two Gas Fired hot water boilers: Capacity input is 2,500,000 BTU/hour, capacity output is 2,000,000 BTU/hour for each of the boilers. The ICA is predicted to utilize **44,000 therms** for space heating.
- Two Gas Fired steam boilers: Capacity input is 175,000 BTU/hour for one boiler and 420,000 BTU/hour for the second boiler. The ICA is predicted to utilize **11,088 therms** for humidification of gallery spaces.
- Two Gas Fired domestic water heater: Capacity input is 160,000 BTU/hour for one water heater and 250,000 BTU/hour for the second water heater. The ICA is predicted to utilize **3,652 therms** for the heating of hot water.

Heating media for the facility is low temperature hot water (HHW) and is distributed to a perimeter finned tube radiation system (See Table 13). The HHW is circulated using a primary-secondary pumping system with temperature reset based on outside air temperature. The secondary pumps are variable volume and powered through variable speed drives The maximum water outlet temperature will be 180^{o}F and minimum return water inlet temperature will be 160^{o}F during the heating season. All HHW control valves located at terminal devices are two-port modulating (air handling units heating coils, fan coil units, hot water unit heaters). Outside air, supplied for ventilation to the air-handling units, is preheated by hot water coils.

OBJECTIVES OF A SUCCESFUL REDESIGN

The purpose of conducting this redesign research is to improve the performance and value of the Institute of Contemporary Art. The primary objective will be to lower the life cycle costs of this building. This includes decreasing costs associated with the consumption of electricity and natural gas as well as with yearly maintenance. The building possesses a high profile and is sure to attract attention, this only being amplified with an environmentally friendly design. The building's original financers are likely to remain owners for the foreseeable future, making a lower monthly utility bill very attractive.

Lowering first costs will be the second primary objective, as the project was delayed for several years due to budget overruns. This is generally in opposition to saving long-term energy savings. However, given the unique cooling and heating systems described here within, this is an obtainable goal.

The third objective of this proposal is to provide a more redundant mechanical system. No redundant mechanical systems or equipment is included in the design. The general strategy adopted is to provide multiple units of all the major equipment sized to have a combined capacity of 100%. In this way, failure of any one of these major components will not result in a complete system shutdown but only in a reduced level of service to the building. Design documents show an assumption that in the event of a power failure or other major building systems failure the building will be closed. By providing redundant systems, the museum would not lose revenue due to an inevitable mechanical failure.

The fourth objective sought in this report is to reduce the building's environmental impact. With a design that substantially decreases building emissions, the building may qualify for a Leadership in Energy and Environmental Design (LEED) certification. This was never even discussed during the design of the Institute of Contemporary Art, but with the enclosed design proposals may become a reality.

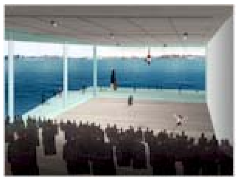
ALTERNATIVES CONSIDERED

Several options were explored before choosing a scheme based upon ocean cooling, solar heating, and desiccant conditioning. The following includes a brief description of various initial ideas that were later disregarded.

A regenerative, duel duct system was initially theorized as a way to save energy and cost. This system would use ‘free’ evaporative cooling for the majority of the year and be supplemented by a chiller during times of greatest cooling needs. Although this system has great savings potentials, it is complicated to understand, makes us of extensive ducting, and has never been applied to a museum application. Thus, this option was ruled out.

Another option considered was to simply decrease the number of air handling units in order to save costs. This was ruled out do to the fact that decreasing these units would reduce overall redundancy in the system. However, it still may be a viable alternative to eliminate AHU-5 and transfer its cooling load to one of the other units.

A third option was to use off peak ice storage as a means of reducing peak demand loads. Although this option would certainly save long term operational costs, the first costs would be very high and would not have been a viable alternative due to the significant value engineering needed to construct the building in the first place. In addition, space is a premium in the Institute of Contemporary Art and storing ice within the building would not have been possible.



PROPOSED REDESIGN

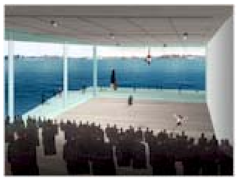
The following section outlines information to implement systems including: (1) ocean source cooling, (2) solar heating, and (3) desiccant conditioning. The objective of next semester's thesis research includes lowering life cycle costs, decreasing first cost, increasing redundancy, and minimizing the building's impact on the environment.

<u>Scope</u>

The heart of this redesign proposal includes drawing cool ocean water from the bottom of Boston's Harbor. A pipe, estimated to be around 1,000 ft in length, would draw water from 45 feet beneath the surface. Data taken from a buoy located ½ mile away during the last 6 years shows that the maximum bottom water temperature approaches 62F during mid August, dropping sharply thereafter. Surface water temperature approaches 66F around the same time, but is more susceptible to changing surface currents. Although 62F is much warmer than typically used by ocean source cooling, proper distribution of this resource throughout the building may serve the Institute of Contemporary Art's entire cooling load. A study will be conducted as to what is the best way to retrieve this water with primary options including either an open loop or closed loop system. To increase redundancy, a second pipe of much shorter length would be able to take advantage of surface water temperatures in the case the main feed would become blocked.

In order to maximize the potential cooling effects from this water, a chilled radiant floor is to be investigated. By running cool water through the floors and ceilings of the Institute of Contemporary Art, the entire cooling load can be met with just ocean source cooling alone. Thus, huge first cost savings can be justified by the removal of the chillers, cooling towers, and all other related equipment. Chilled floors have some technical problems associated with them including condensation and stratification of the air. The potential for condensation would be minimized by the shear fact that concrete has absorptive properties and would absorb any condensation for a short period of time. In addition, sensors would be placed to maintain conditions exactly at 50% +/- 5% relative humidity. The system would also have the capability to shut down if relative humidity reached critical levels due to an unanticipated breach of the building envelope. Warm air rises, which creates stratification in a space utilizing a chilled floor. This has the potential to create uncomfortable conditions if the difference in temperature between the floor and an occupant's upper body exceeds 4 degrees. This negative effect will be further investigated with the following potential remedies including: (1) using the large floor area to increase required floor temperatures, (2) using high induction supply air diffusers in an attempt to mix the air, and (3) using concealed paddle fans to draw cool air up and warm are down.

This same radiant system can also be used to run warm water throughout the building during times of heating. Combining the heating water and cooling water into one set of tubes inset in concrete will further reduce first costs. Radiant heating is an extremely



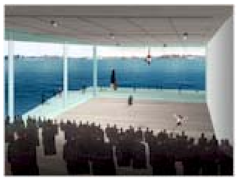
efficient and proven way to heat a space, improving both performance as well as comfort. Little negative impacts would result from the use of this heating method.

Due to the relatively mild water temperatures needed to heat the Institute of Contemporary Art, a hot-water solar array will be investigated to supplement the need for boilers and natural gas. These hot water collectors would be located on the roof, where existing north-facing skylights coving over 75% of the roof and provide for perfect solar positioning. A hot water storage tank would store heated water during times of ample sun for use during night hours and cloudy days. The storage tank may be quit large and thus would represent a significant structural load on the building. This tank might be turned into a 'modern' art form and displayed in glass rising from the lobby on the first floor. This system would use heat exchangers and an antifreeze solution to provide reliable and maintenance free performance. The system could also be run backwards to melt any snow pack or ice that may form, reducing the structural load on the building and maintaining a path for natural daylight to travel.

With the sensible cooling and heating loads being completely covered by the radiant systems proposed for the Institute of Contemporary Art, the air handling units can be significantly downsized to only provide ventilation air. For example, AHU-1 can be downsized from 21,150 cfm to only 8,010 cfm. This provides for significant reductions in AHU size, ductwork tonnage, and fan energy. Related electrical equipment and motors may also be reduced including the footprint. This may free up more space to be used for displaying artwork.

While the radiant floors can carry the entire sensible load, 62F water during the summer months is not enough to dehumidify the air and consequently cannot meet the latent load. Thus, an active dual-desiccant wheel system will be incorporated into the air-handling units. Wheels covered in desiccant will revolve between the supply and return air streams. The desiccant absorbs moisture in the supply air stream and releases it into the exhaust airstreams only to be ejected from the building. Very low reactivation temperatures of between 130F and 150F will be investigated in order that free energy delivered from the solar panels could be utilized during summer months to drive moisture out of the supply air stream. This lends itself well since the summer months tend to produce the sunniest days and consequently the warmest water temperatures. Thus, solar heated water would play an integral part of conditioning the museum both during the winter months as well as during the summer. A direct fire boiler would run when solar capabilities fall short of the reactivation temperatures needed, thus providing additional redundancy in the system.

These very same desiccant wheels can also be used to humidify dry outside air in times where the indoor humidity levels drop below 50%. Use of an indirect evaporative cooler will be investigated during times of extremely low outdoor humidity levels and no internal latent gain. Thus, the existing steam humidification system and related steam boilers would be eliminated. Further investigations into enthalpy wheels, heat



exchangers, sensible wheels, and desiccant wheels will provide for the optimum arrangement and life cycle cost reductions.

Justification

This report has identified many of the design restraints, criteria, and system components to give a detailed overall picture of the mechanical systems within the Institute of Contemporary Art. Due to the nature of this museum, energy efficiency, simplicity, and reliability took a backseat to bigger program needs such as architecture, structure, and natural day lighting. First cost had a huge influence on the mechanical system design. Construction was delayed more than a year due to gross budget overruns and redesigns. With these aspects in mind, an overall critique of the system is presented.

Due to the lack of mechanical redundancy in the HVAC design, it is likely the Institute of Contemporary Art will incur higher premium insurance costs over the long term for preserving / exposing artwork in its facility. Further increases could occur due to the fact that pressurized water is present in all the gallery spaces. Both perimeter radiant and sprinkler systems pose a possible risk. A dry sprinkler system was initially proposed only to be value engineered out of the final plans. In the case of mechanical reliability issues, the ICA could also lose the ability to display particularly environment sensitive or valuable artwork, creating an impact on the operation of the gallery space over the years. However, the design does allow for the possibility to upgrade to a level of redundancy to that of other institutions.

Energy simulations predict that the ICA will use approximately **58,740 therms** (5,874,000 kBTU) per year with an annual predicted cost of **$67,077** for annual natural gas consumption. It was found that buildings similar to the Institute of Contemporary Art consume less than **1,231,632 KWh/yr** of electricity. A detailed model was carried out in Carrier's Hourly Analysis Program v.4.2 showing that the Institute of Contemporary Art is actually predicted to consume **2,455,890 kW/yr, almost twice that of other museums of comparable size**. Using Nstar utility rates, the annual electricity consumption cost is estimated to be **$228,361.** The relatively high use of energy is also paid for in lost usable space. Approximately **8,700ft^2**, or approximately **14%** of the ICA is 'unusable' space due to Utility space.

The total initial start-up construction cost estimate for the ICA building is $33,667,308. Actual Bidding data from HVAC, Electrical, Plumbing, and Fire Protection shows a first cost for these systems to be $10,259,527. The net present value for mechanical, electrical, plumbing, fire protection, and elevator services at the Institute of Contemporary Art (ICA) building is $16,570,577, almost half of the overall first cost. Thus, long term predicted operating costs would cost the Institute of Contemporary Art large sums of money. This energy results in a significant environmental impacts as well as being a financial burden. The ICA is predicted to release 1,622 pounds of particulates, 18,511 pounds of So2, 11,484 pounds of Nox, and 3,388,561 pounds of C02. The Institute of Contemporary Art is a bold architectural statement and is sure to attract the attention of all who pass by, but it comes with a hefty energy price tag as well as environmental impact.

Ocean cooling, solar heating, and desiccant wheels hold the potential to lower life cycle costs, decrease first cost, and substantially lesson environmental impacts. In addition, this building may then qualify for a LEED rating, with the potential to gain additional public acknowledgement. Additional cost-saving measures will be discussed in the breadth areas of the report.

<u>Coordination & Integration</u>

Coordination will have to be examined closely to maximize the space-saving potential of this design. The biggest foreseeable issue with this design is the placement of the large hot water storage tank needed to store solar thermal energy. The exact size of this tank is presently unknown, but coordination will have to occur to minimize changes in the building's structure and architectural program. The locations of radiant floors will need to be thoughtfully calculated so that further changes in floor plans would not impact the integrity of the system. Removing ducts currently running in the roof trusses and moving them to below the forth floor will require coordination with existing conditions. The ocean pipe entrance will need to be coordinated with the lobby space, outside deck, and large rocks placed to minimize erosion. Placement of the air-handling units should allow for cross connection and thus redundancy. Solar panels on the roof should be coordinated so that the impact on natural light reaching the gallery space be minimized, if not improved. Changes to the angles of the north-facing skylights need to be coordinated with existing structural column placement. Most importantly, architectural integrity should be preserved throughout this entire process.

BREADTH AREA: STRUCTURAL

With significant reductions in outside air usage resulting from radiant flooring, large diameter supply air ducts running in the roof trusses of the Institute of Contemporary Art can be downsized. This reduction allows the ducts to be removed entirely from the roof trusses and placed below the forth floor gallery. Consequently, the expensive roof space frame designed to house these ducts can be redesigned. It is proposed that a simple truss be utilized, further reducing first costs. The depths of these trusses can also be decreased allowing for a higher gallery ceiling height. Further cost and weight savings can be achieved, as the drywall enclosures are no longer needed.

BREADTH AREA: LIGHTING

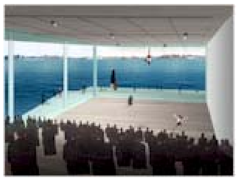
The daylight delivery system consists of a series of horizontal north-facing skylights. The system allows for changes in direct solar radiation on the roof to be dampened out. The skylights include a perforated reflector that improves ceiling luminance uniformity by reducing light towards the south and increasing light toward the north. The 4th floor galleries have translucent ceilings made up of specially formulated fabric. This fabric is 100% Trivera CS and white in color producing a visible light transmission of at least 70%. Mechanical blackout shades, linked with the building control system, provide for the optimum amount of light passing through the skylight system. Significant improvements in the gallery day lighting system are possible with the removal of ducts from the roof of the Institute of Contemporary Art. The angles of the skylights can be extended, allowing for a more uniform light appearance on the ceiling. This has the added benefit of giving more surface area for the radiant panels on the roof.

BREADTH AREA: ELECTRICAL

Electrical power for the Institute of Contemporary Art is obtained via a single 480V, three phase, 4 wire service provided by the local Electrical Utility Company. The transformer, provided by the Utility Company, is pad mounted at grade. Electrical drawings call for 2500 amps @ 480V, 3 phase electric service. With significant reductions in the electrical demand used by the heating and cooling systems, these panels and related transformers can be downsized. The provision of a 450 kW Emergency Diesel Generator is installed on the First Level of the Institute of Contemporary Art and will provide the ICA with a source of standby power. It may be possible to link portions of the heating and cooling system to the standby power system in order to maintain partial control of indoor environmental conditions. Currently, it is assumed the building will be closed and indoor conditions cannot be maintained in the case of an electrical power failure.

SUMMARY OF REDESIGN PROPOSAL

1. Ocean Source Cooling Pipe reaching depths of over 45ft (over 1000 ft long)
2. Installation of ocean water pumps with redundant backup.
3. Elimination of chillers, cooling towers, and related equipment
4. Installation of radiant flooring for both cooling and heating
5. Installation of solar panels affixed to existing north-facing skylights
6. Installation of two thermal hot water storage tanks
7. Removal of half of the existing boilers and domestic hot water tanks
8. Installation of enthalpy wheels to remove and add humidity
9. Removal of the steam humidification system and related equipment.
10. Installation of indirect evaporative coolers on exhaust air stream path for very dry conditions
11. Decreased air handling unit size to supply ventilation air only
12. Decreased ductwork cross-sectional area
13. Installation of needed controls for the changes in mechanical system
14. Decreased need for acoustical dampers due to significant noise reductions in system
15. Relocation of ductwork currently running in roof to below the fourth floor.
16. Replace the roof space frame with simple joists
17. Extend the angle of the north-facing skylights to improve natural day lighting and increase surface area for solar panels.
18. Resizing of all the related electrical equipment
19. Installation of pumps associated with radiant flooring
20. Removal of all the fan coil units and perimeter fin tube radiant heating
21. Replace the double layered sprinkler system with transparent heat shield
22. Link emergency generator to environmental system for gallery spaces to provide for backup in the case of electrical failure.



PROJECT METHODS

The research and modeling for this proposed redesign would be accomplished using a variety of design tools and methods. The redesign process will begin with modeling the desiccant wheel performance, followed by the ocean cooling and solar heating. Obtaining buoy data on local ocean water temperatures will be the first step in conducting research.

A single-zone program will be written in Engineering Equation Solver (EES) to establish the general feasibility of the system followed by a comprehensive, whole-building model. Data from Carrier's Hourly Analysis program will be exported into this EES program and electrical and natural gas yearly consumption predicted. These results will then be compared to existing energy modeling and the results scrutinized to obtain a prediction on the long-term economic viability of the system. Maintenance costs will also be factored into the life cycle cost analysis.

Redesigns to the building's roof structure will be analyzed first by hand and then using STADD to calculate bending moments and shear forces. Subsequent resizing of columns and floor joists will be kept to a minimum. Additional loading due to the hot water storage tank, solar panels, and radiant flooring system will also be addressed with structural engineering software.

Electrical redesigns and downsizing will confirm to applicable building codes and the 2002 National Electric Code. Microsoft Excel will reduce time and increase accuracy of the results. Day lighting modeling may be done to prove that redesigns to the north-facing skylights improve natural day lighting and uniformity.

Finally, a detailed cost estimating technique utilizing predicted costs from RS means would be calculated. This data will then be compared to detailed construction cost estimates from the original design.

PRELIMINARY RESEARCH

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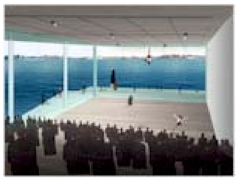

March 2005

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1 Begin structural redesign using STADD	2	3	4 Finish structural redesign using STADD	5
6	7 Spring Break	8	9	10	11	12
13	14 Begin resizing electrical equipment	15	16	17	18 Finish resizing electrical equipment	19
20	21 Begin acoustical analysis and fire protection	22	23	24	25 End acoustical analysis and fire protection	26
27 Begin thesis report	28 Begin first cost detailed analysis	29	30	31 Finish first cost detailed analysis		

February 2005

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1	2	3	4 Finish detailed schematic diagrams	5
6	7 Selection of mechanical equipment	8 Begin layout of ductwork	9	10	11	12
13	14	15	16	17	18 Finish layout of ductwork and equipment	19
20	21 Start detailed whole building model in EES	22	23	24	25	26
27	28 Finish detailed whole building model in EES					

January 2005

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2	3	4	5	6	7	8
9	10 Begin detailed research into desiccant wheel design	11	12	13 Desiccant wheel research complete	14 Solar research complete	15
16 Export HAP analysis data	17 Obtain an equation for ocean water temperature	18 Begin writing basic 1-zone model in EES.	19	20	21 Complete basic model (adjustable parameters)	22
23	24	25 Begin detailed schematic diagrams	26	27	28	29
30	31					

April 2005

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1 Finish thesis report	2 Start Thesis Presentation
3	4	5	6 Finish thesis Presentation	7	8	9
10	11 Thesis Presentations	12 Thesis Presentations	13 Thesis Presentations	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30 My Birthday!